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Impact of Control Availability on Perceived Comfort

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Abstract

Open plan offices are known for improving the interaction among occupants while risking their comfort. Traditionally considered to be caused by deprivation of privacy and safety, the discomfort is also recently attributed to occupants' lost of control availability. According to some studies, improving perceived control could improve perceived comfort. However, few studies investigated the correlation with variations of control availability. An investigation is therefore presented in this paper that examines the impact of different levels of control availabilities' on perceived thermal comfort, for which a potential gap of thermal neutrality was identified as the availability of control increased.

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Keywords:

1. Introduction

M than 70% of people employed in the United States work in open plan offices [1], yet according to Kim et. al, more than 10% of them are not satisfied with their workspace environment [2]. This was foreseen by some of the original designers for open plan offices. As a designer for the first open plan office prototype - the Action Office II , George Nelson was worried as early as in 1960 that open plan offices may be 'simply a way of cramming in a maximum number of bodies' [3]. His worries were validated by the reported loss of sense of privacy and security as well as sense of comfort across the board. Increased noise, distractions, perceived crowding and decreased privacy as well as eye-fatigue were reported, triggering self-motivated modifications towards the thermal environment [4]. Further research attributes such complaints to decreased environmental satisfaction, increased cognitive workload and sick absence [5,6]. Many efforts addressed such challenges, ranging from building engineering of various specialties eventually contributing to increasing system complexity, leading to a continuous loss of control availability for the occupants and

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eventually, leading to increased discomfort [7]. This may lead to frustration and health implications despite the adaptability of the occupants [8].

Such challenges have since been addressed in quite a number of studies, examining the possibility of allowing more controls for the occupants. Among them, some have been able to verify a positive correlation between improvements of visual, acoustical comfort with increased control availability. Few were able to establish similar correlation between control availability and perceived thermal comfort [9]. Some precedents have been set by Paciuk et al. [10] that perceived control can increase thermal comfort, as was identified by Langevin in 2012. [11] This paper presents an experimental analysis that addresses this caveat such that further investigation may be encouraged and investigated.

Nomenclature

MRT	mean radiant temperature (˚C)
PMV	predicted mean vote

2. Background

It was identified as early as 1970 that open plan offices' main appeal is the 'lower overall cost and higher productivity' [12]). To better understand what that entails, we can plot the rent percentage of corporate spending against the major recessions in the 20th century to establish the relationship between the evolution of open plan as in Figure 1.

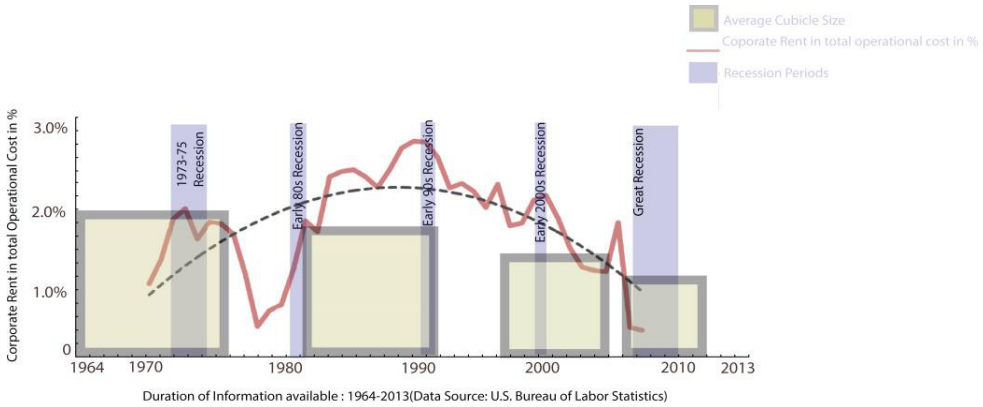

Fig. 1 Correlation between cubicle size and economic environment

Figure 1 depicts an inclination of rent percentage drop during each major recessions. The averaged workspace (or the conceptual cubicle size, if one may perceive it as such), on the other hand, continued to shrink. The driving forces and other externalities are not taken into account. It is reasonable to extrapolate from the Figure 1 that should another recession take place, rent percentage will continue to drop, which could result in an even smaller average workspace size. As according to the study from Kim et al. in 2013 where average workspace area was found to be the most important factor contributing to workspace dissatisfaction, the struggle to ensure occupant comfort in open plan offices seems like it could stretch on [2].

This might lead to even more challenge in providing adequate control availability towards the occupants, since many studies have identified the perception of control in shared office spaces being reduced [13]. Some has even established such dissatisfaction to be correlated with the depletion of control availability [14], that the perceived comfort can be expected and compensate each other when occupants are allowed to make adaptive comfort decisions.

3. Method

To better understand the relationship between control availability and thermal comfort, an experiment was designed to investigate their correlations. A placebo controller was designed and used in the experiment with the response of the occupants registered into a database such that their response can be further analyzed with respect to time.

3.1. Highlights

Before going into the details of the experiment setup, a few highlights of the experiment are elaborated to elaborate the design intentions.

The overall design concept of the experiment was to provide occupants access to an adaptive thermal comfort control method. This is often observed in offices that are insufficiently heated. Instead of tapping into the heating system of the room where the experiment is conducted, this method was believed to be more intuitive and convincing for the ocupants.

Similarly, the experiment was designed to provide fast and reliable confirmation for occupants after a control attempt that their control is received. This has been demonstrated to be a significant criteria for occupant satisfaction [15]. The experiment was therefore designed to include both a 'clickable' relay that produce discernible clicking sound as the experiment proceeds and a page of confirmation that the response was logged and processed.

Thoughts were also put into the method of group assigning, respectively the 'complaint' and 'control-available' groups. Instead of using the traditional 'test' and 'control' group, two different names were chosen to avoid confusion for the two groups by avoiding potential psychological verbal implications for the occupants: The use of 'complaint' is consistent with conventional commercial building operations where occupants make complaints to building services or facilities department and wait for long-distance control actions. The 'control-available' group, on the other hand, will promise occupants an increased sense of control beyond simply communicating with the facilities, but actually taking matters to their own hands. The two groups also deliberately designed to counteract the Hawthorne effect so that both will have a false positive impact on productivity regardless of the group assignment.

Also, the selection of the material for the 'actuator' - the placebo controller was Styrofoam, which was also deliberately chosen. Its thermal diffusivity was marked by the manufacturer as 0.03 W/(mK). This would create a false sense of warmth when occupants attempt to check for the performance of the device [16]: when in question whether the actuator of the control is in fact working, participants may be misled by the heat trapped between their hands and the Styrofoam.

3.2. Setup

The schematic of the room for the experiment can be found in Figure 3 along with the diagram fo flow of data during the experiment.

For the flow of data, occupants' control responses were read through a web interface and sent to the wifi-based Spark Core such that the corresponding relay can activated accordingly creating 'clicking' sound. The control attempts are simultaneous logged into a MySQL database with time stamps by codes embedded in the PHP files.

Meanwhile, the actual temperature, relative humidity and mean radiant temperature (MRT, calculated from a globe thermometer as according to Kuehn et al. [17]) were collected through sensors and sent to an independent Arduino board throughout the experiment with time stamps.

Heating elements constructed from Styrofoam heating pads will be demonstrated to be able to heat up to 34 ˚C before the experiment. Participation from the occupants was welcomed, yet during the experiment, the heating elements will not be wired properly to have any power supply for the duration of the experiment, working only as placebo actuators.

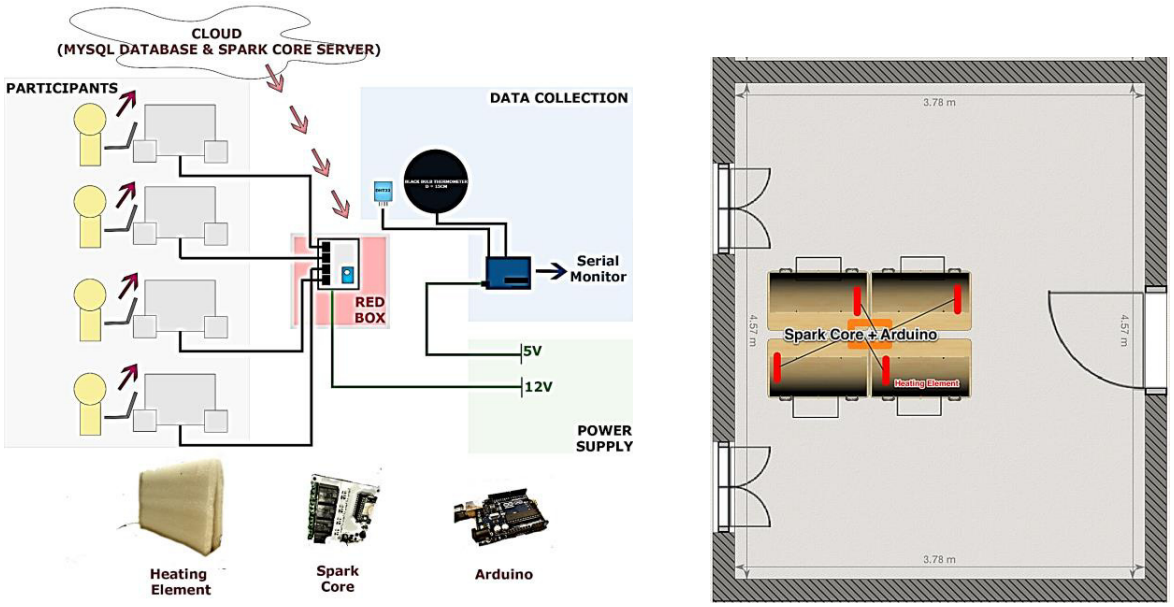

Fig. 2 Representation of the flow of data and experiment setup (left) and physical setup of the experiment (right)

3.3. Experiment procedure

Four volunteers (2 male, 2 female of 24±v2 years old) wearing typical winter clothes with a clothing factor of 1.37 [14] were invited to participate the experiment. During a brief introduction on the purpose of the experiment with a short demonstration of the performance of heating element, the participants were made aware of the aim of understanding the correlation between thermal comfort and control behaviors. A 10 minutes' acclimatization period then take place prior to the 25-minute experiment. After the experiment, a brief interview was conducted to obtain the occupants' opinion on the performance of the heating elements.

4. Result

The responses, as plotted in Figure 3 showed a very interesting gap of control attempts from the 'control available' group: This noticeable gap can be observed for the 'control-available' group between the first and second spur of control attempts , while the 'complaint' group remained very consistent for the duration of the experiment. During the

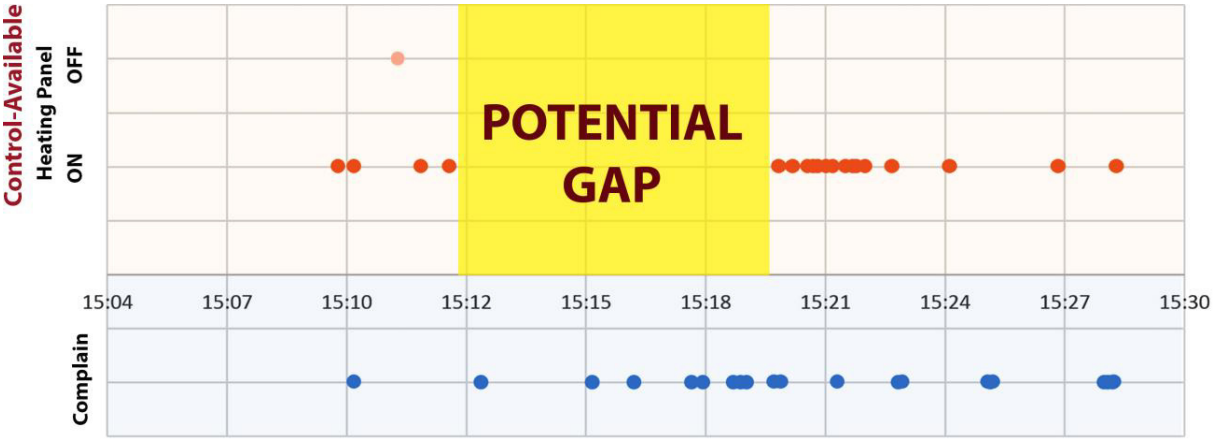

Fig. 3 Control Responses from both groups during the experiment

first three minutes of the experiments, the 'control-available' group exhibited a stronger inclination to make adjustment than the 'complaint' group with an average of 2 responses per minute comparing to the 0.5 responses per minute. This is consistent with the observation that people are inclined to make complaints when they are convinced they are extremely uncomfortable [15]. Following the spur of responses, however, a noticeable gap could be identified in the 'control-available' group. For approximately 7 minutes, no control actions were performed. This could suggest a period of perceived thermal neutrality for the 'control-available' group. Another spur of control action then took place and lasted for approximately 3 minutes in the 'control-available' group before the control actions become regular till the end of the experiment.

The similarity exhibited in the periodic response during the second half of the experiment could be explained by the response obtained after the experiment where more than 50% of the participants suggested that they realized the controller could be a placebo towards the end of the experiment.

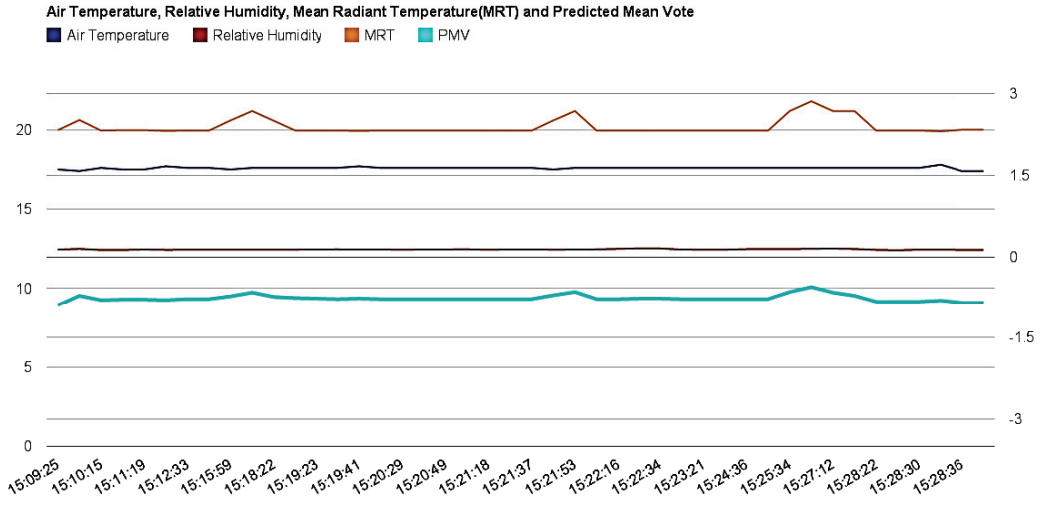

Fig. 4 Fluctuation of Ta, RH, MRT and PMV during the experiment

As could have been anticipated from Figure 4, the temperature profile during the experiment remained roughly unchanged, with a mere 0.6% change in air temperature, a 10% fluctuation in relative humidity and a 4.8 change in mean radiant temperature, resulting in a 3% change in PMV. This was all within the margin of errors of the sensors that were used for the experiment.

Overall, it appears that despite the same thermal environment, by providing the ability to ‘control’ beyond ‘complaining’, occupants could be more inclined to make interventions and could have a ‘perceived-neutrality’ period after they considered the controls to have taken effect. People who made the complaint, on the other hand, remained consistent throughout the experiment.

We recognize a few potential sources of errors for the analysis presented - relatively small sample size and a lack of change in the thermal environment are two aspects that can be easily improved for future investigations. Increased sample size, to begin with, could add more statistical significance to the results. Increasing the test scenarios where temperature actually changes could potentially lead to more interesting results by comparing the responses with PMV values. One potential direction for investigation is to slowly change the overall thermal environment throughout the experiment (leading to a minimizing PMV value) and, if possible, pre-testing the occupants for individual PMV calibrations so that the control availability can be better corroborated with perceived thermal comfort. The real challenge then will probably be differentiating the fluctuation of PMV in a large group from the increase of perceived thermal comfort due to increased control availability.

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